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## EFFICIENT CONTROL REGIMES FOR THE THERMAL AND TECHNOLOGICAL PROCESS OF GLASSMAKING IN TANK FURNACES FOR FLOAT-GLASS PRODUCTION

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The basic principles for controlling the thermal and technological regimes of the glassmaking process in furnaces used for sheet-glass production by the float method are presented. Fuel delivery is redistributed above the melting zone in order to improve the operating efficiency of the glass furnace. The technical results of using an efficient distribution of the thermal loads over the burners in the furnace is lower energy consumption in the melting process and higher product quality. It is important to maintain the prescribed level of iron oxides in the glass and to monitor the oxidation-reduction potential during the glass melting process.

***Key words:*** thermal and temperature regime, maximum thermal loads, distribution of thermal loads, total thermal load.

An important factor in increasing furnace efficiency in the production of sheet glass in modern glassmaking furnaces is the optimization of the physical-chemical processes in the preparation of the glass batch [1] and methods of feeding batch into the furnace [2].

At the same time practical experience shows that the decisive factor in obtaining high-quality molten glass and obtaining high-grade product is an efficient organization of the thermal and temperature regimes of the glassmaking furnace.

For a long time research has been conducted on two float-lines at Salavatsteklo, JSC (Nos. 1 and 6) in order to determine the optimal thermal and temperature regimes (over a period of five years on furnace No. 1 and six years on furnace No. 6). The molten-glass capacities of the furnaces Nos. 1 and 6 are 500 and 600 tons/day. As a result the basic principles for conducting and monitoring an efficient technological regime for making molten glass were determined for these furnaces.

It is well known that glassmaking furnaces can be operated under the most diverse thermal load distributions over the melting tank. However, a general principle for conducting these regimes is to control and regulate them on the basis of the temperatures in the gas space in the batch heating zone (the zone with thermal loads exceeding 60% of the total fuel consumption of the furnace).

Regimes with the maximum thermal loads distributed on the burner pairs I, II and IV are used to intensify the glass melting processes. In this case the maximum temperature in the gas medium is created in the region of the burner pair IV (hotspot section). The thermal load up to 40% of the total heat load on the furnace is maintained in the fining zone.

When the temperature of the molten glass changes in the conditioning zone the regime is adjusted by regulating the loads on the last burner pairs. This could be the reasons why the number of gas inclusions in the molten glass increases, the surface layer of the melt becomes overheated and therefore the thermal uniformity of the molten glass decreases.

The most common practice in the production of float-glass is to use a system for controlling the thermal and technological regimes of the glassmaking process. To implement such a system the maximum thermal load is set on the burner pair IV with the fuel consumption increasing in the batch zone and the thermal loads above the zone of heavy foam subsequently decreasing [3].

The main drawback of all known methods is a rise in the temperature — the maximum over the gas medium — to above 1600°C, i.e., to the maximum normal operating temperature of the refractories in the furnace brickwork. As a re-

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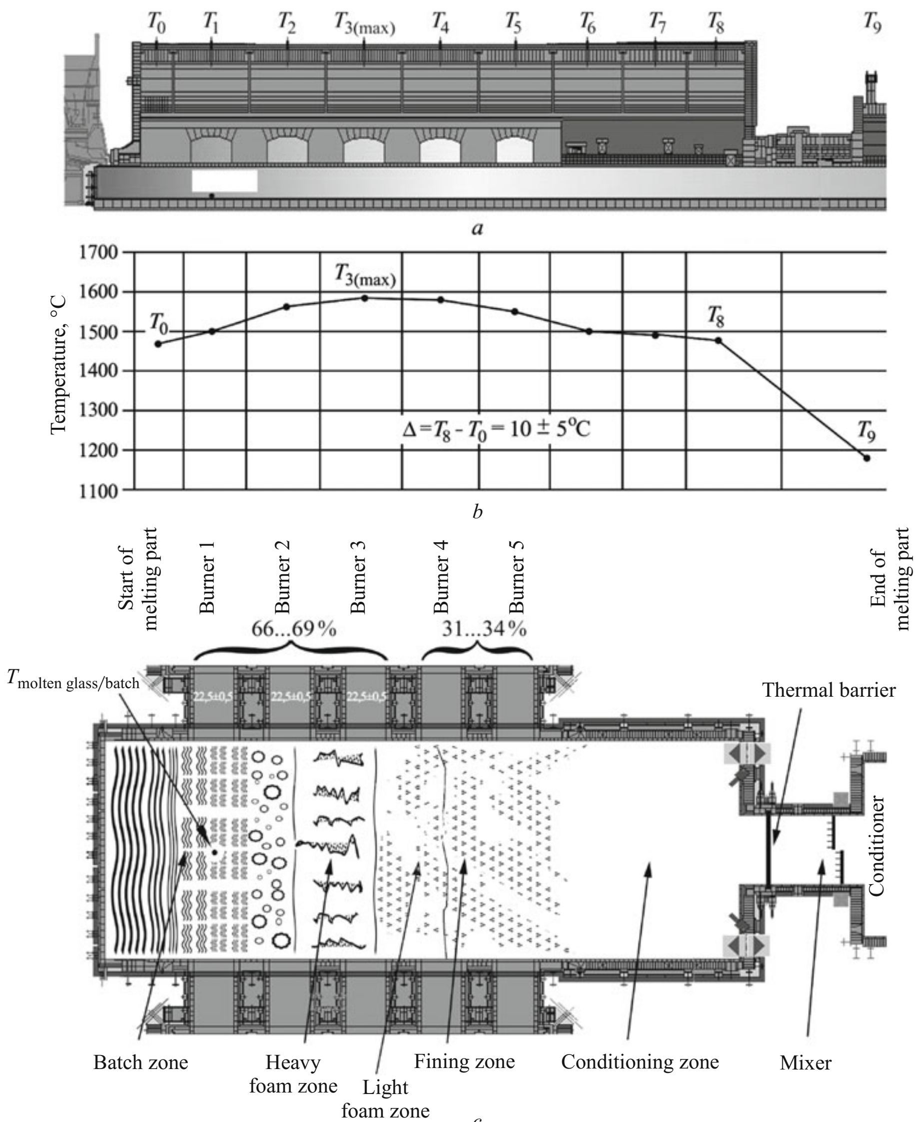


**Fig. 1.** Control scheme for the thermal and technological regimes of a glassmaking furnace for float-glass production: *a*) arrangement of the thermocouples on the furnace roof ($T_0$ ... $T_9$); *b* ) temperature distribution over the gas space of the furnace; *c*) furnace layout.

sult, in most cases the service life of the furnace is reduced and additional defects in the form of refractory inclusions form in the glass. In addition, the fuel consumption on the process increases.

The research work performed on the lines Nos. 1 and 6 made it possible to develop the basic principles for controlling the thermal and technological regimes of the glass-making process. The main technical results of using this control scheme are a reduction of the energy consumption for melting and higher product quality.

These results were achieved by feeding fuel into the batch heating zone and establishing the maximum heat load in a definite burner pair. This made it possible to increase the operating efficiency of the five-burner furnaces Nos. 1 and 6.

Compared with the existing solutions the fuel fed to the burners in the furnace is redistributed in a manner so that the total thermal load on the first three burners above the melting zone is 66 – 69% of the total thermal load on the furnace with the same 22.5 ± 5% thermal load on each of three burners. In addition, the maximum over the gas medium is established in the region of the burner pair III, as a result of which the hotspot approaches the glass-melting zone (see Fig. 1).

Under these conditions the positions of the batch-melting boundaries are better stabilized and heat-exchange between the batch and molten glass is more intense.

In turn the position of the temperature maximum in the region of the burner pair III is reached as a result of intense heat extraction in the zone of active heating of the batch in the action range of the first two burner pairs. This process is controlled by the thermocouple $T_{molten\ glass/batch}$, located in the bottom layers of the molten glass in the batch-heating zone (see Fig. 1*a* and *c*).

A total thermal load equal 31 – 34% of the total thermal load on the furnace (see Fig. 1*c* ) is established on the burner pairs IV and V in order to activate the fining and homogenization processes in the molten glass.

To stabilize the parameters of the free-flow cycle of the convection flows of the molten glass and build up a store of heat to compensate for the heat losses due to factors such as a change in the batch/cullet ratio (toward higher values) and decrease of the caloricity of the fuel the difference between the gas temperatures at the end of the melting tank (according to the indications of the thermocouple $T_8$) and at the start of the batch-melting zone ($T_0$) in front of the first burner pair (see Fig. 1*a* and *b*) is maintained at the 10 ± 5°C.

In the production of float glass the use of the efficient scheme developed at Salavatsteklo, JSC to organize the thermal and technological regimes of the Nos. 1 and 6 furnaces made it possible to decrease the energy consumption in the melting process to 1400 – 1500 kcal/1 kg molten glass and to increase the quality of the final product by more than 5%. As a result of the reduction in the fuel consumption plans are afoot to increase the service life of the furnaces Nos. 1 and 6 to 12 or more years.

The scheme developed for organizing and regulating the thermal regime of a float-glass furnace is effective and makes it possible to produce high-grade product with a stable content (by weight) of iron oxides in the molten glass at the level 0.070 – 0.075%.

However, special technological approaches to organizing the temperature regime are required in order to obtain high-quality molten glass with low content of iron oxides (< 0.07 wt.%) and high content of iron oxides in the molten glass (> 0.075 wt.%) for stable production of high-grade product.

Research has shown that for iron oxide content in the glass below 0.065 wt. % the bottom layers of the molten glass are heated up and the temperature in the gas space of the furnace decreases significantly. For iron oxide content in the glass above 0.075 wt. % the temperature of the bottom layers decreases and the temperature in the gas space increases. As a result the bottom layers of the molten glass which are contaminated by foreign inclusions rise in the first case and the scheme of the convection flows of the molten glass along the entire length of the furnace becomes unstable in the second case. The quality of the final product decreases in both cases.

In this situation it becomes very difficult to control the thermal and technological process of melting glass and to establish the conditions required for stable production of high-quality glass. Technologically effective means for maintaining a constant content of iron oxides in the glass and controlling the redox processes in glass melting are required. These are the most pressing problems of improving the production sheet glass by the float method.

Work in this direction will be continued.

## REFERENCES

1. V. I. Litvin, I. D. Tokarev, and A. V. Yachevskii, "Optimization of the physical-chemical processes in the preparation of glass batch and evaluation of the effect of its moisture content on the effectiveness of the glassmaking process," *Steklo Keram*., No. 8, 19 – 23 (2010); V. I. Litvin, V. D. Tokarev, and A. V. Yachevskii, "Improvement of batch preparation and feeding for glass furnaces," *Glass Ceram*., **68**(5 – 6), 139 – 142 (2011).
2. L. Ya. Levitin, V. I. Litvin, V. D. Tokarev, and A. V. Yachevskii, "Improvement of the batch preparation and feeding process in a glassmaking furnace," *Steklo Keram.*, No. 5, 3 – 6 (2011); L. Ya. Levitin, V. I. Litvin, V. D. Tokarev, and A. V. Yachevskii, "Increase of glass manufacturing efficiency using cullet in float-glass production," *Glass Ceram.*, **69**(5 – 6), 143 – 145 (2012).
3. L. Ya. Levitin, L. M. Protsenko, N. A. Pankova, et al., "Improvement of the thermal regimes of glassmaking furnaces," *Steklo Keram*., No. 5, 7 – 8 (1984); L. Ya. Levitin, L. M. Protsenko, N. A. Pankova, et al., "Improved heat schedules for glass furnaces," *Glass Ceram*., **41**(5), 212 – 215 (1984).
4. *Method of Controlling the Thermal and Technological Process of Glassmaking in Tank Furnaces for Sheet-Glass Production by the Float Method* [in Russian], Patent granted on August 8, 2013; Patent application No. 2012119066/03 (028735).